Abstract — This communication provides the experimental assessment of an efficient near-field – far-field (NF–FF) transformation with spherical spiral scanning for elongated antennas, which allows a remarkable measurement time saving with respect to the classical spherical NF–FF transformation. Such a saving is due both to the use of continuous and synchronized movements of the positioning systems and to the reduced number of NF data to be acquired. This technique relies on a nonredundant sampling representation of the probe output voltage, obtained by using the unified theory of spiral scans for nonspherical antennas and adopting a prolate ellipsoidal modelling of the radiating source. An optimal sampling interpolation scheme is then used to efficiently recover the NF data needed by a probe compensated NF–FF transformation with spherical scanning. The experimental tests have been carried out at the UNISA Antenna Characterization Lab and both the reported NF and FF reconstructions assess the effectiveness and reliability of the technique.

slide 1

Continuous and synchronized movements of the positioning systems of the probe and AUT allow the reduction of the time required for the scanning, which is nowadays very much greater than that needed to carry out the NF–FF transformation.
This innovative transformation is based on the nonredundant sampling representations of electromagnetic fields and employ proper optimal sampling interpolation expansions to recover, from the collected nonredundant samples, the NF data needed by the NF–FF transformation with spherical scanning.

slide 2

When considering elongated antennas, the spherical modelling gives rise to a worthless increase in the number of the NF data to be collected. To overcome this drawback, a prolate ellipsoid can be employed to reduce the redundancy of the spherical antenna modelling. As a matter of fact, the overall number of samples at Nyquist rate needed for the reconstruction on a closed surface enclosing the AUT is related to the area of the modelling surface S.

slide 3

To perform the experimental validation of the proposed technique the FF patterns in the principal planes E (slide 8) and H (slide 9) reconstructed from the nonredundant NF samples collected along the spiral have been compared with those (references) obtained from the NF data directly acquired on the classical spherical grid. In both the cases, the same software package implementing the standard spherical NF–FF transformation has been employed to get the FF reconstructions.

slide 4

The spiral NF samples are employed to reconstruct the NF data at the points of the classical grid via the two-dimensional optimal sampling interpolation formula of central type. The former interpolation is performed along the spiral in order to evaluate the intermediate samples, i.e., the NF values at the intersection points between the spiral and the meridian passing through the output point P. These last are then interpolated to retrieve the NF value at P in a quite similar way.

slide 5

The experimental tests have been performed in the anechoic chamber of the UNISA Antenna Characterization Lab, which is provided with a roll (φ axis) over azimuth (ϑ axis) spherical NF facility. The considered AUT is a X-band resonant slotted waveguide array, located on the plane $y = 0$. It has been obtained by making 8 round-ended slots on both the broad walls of a tapered rectangular waveguide and is fed via a coaxial to rectangular waveguide transition. Such an antenna has been fitted by a prolate ellipsoid with major and minor semi-axes equal to 6λ and 1λ, respectively. The probe output voltages have been acquired by an open-ended WR90 rectangular waveguide along a spiral wrapping a sphere with radius $d = 15.07\ \lambda$.

slides 6-7

The reconstructions of the amplitude and phase of the probe voltage V_1 on the meridian at $\varphi = 0°$ are reported in slides 6 and 7. As can be seen, there is a good agreement between the reconstructed voltage and that directly acquired, save for the zones characterized by a very low level (below about –60 dB), wherein the error is due to the noise and the residual reflections from the anechoic chamber walls.

slides 8-9

These slides show the comparison of the FF patterns in the principal planes reconstructed from the nonredundant NF samples collected along the spiral with those (references) obtained from the NF data directly acquired on the classical spherical grid. As can be seen, all reconstructions are very accurate, thus confirming the effectiveness of the described NF–FF transformation with spherical spiral scanning.

slide 10

It must be stressed that the number of employed samples is 918, significantly less than that (5 100) needed by the MI software package which, as already stated, implements the standard NF–FF transformation with spherical scanning.

2013 Loughborough Antennas & Propagation Conference

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11 -12 November 2013 - Loughborough , UK

EXPERIMENTAL PROOFS ON AN EFFECTIVE NEAR-FIELD TO FAR-FIELD TRANSFORMATION TECHNIQUE WITH SPHERICAL SPIRAL SCAN SUITABLE FOR LONG ANTENNAS

F. D'Agostino, F. Ferrara, C. Gennarelli, R. Guerriero, M. Migliozzi

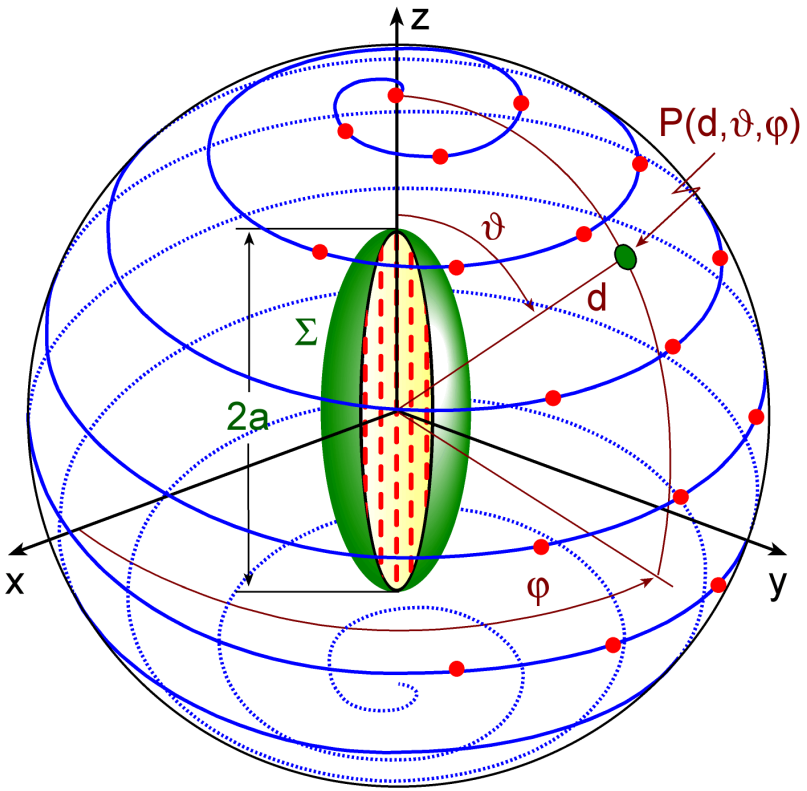
University of Salerno, Italy

RWTH AACHEN UNIVERSITY

University of Kent

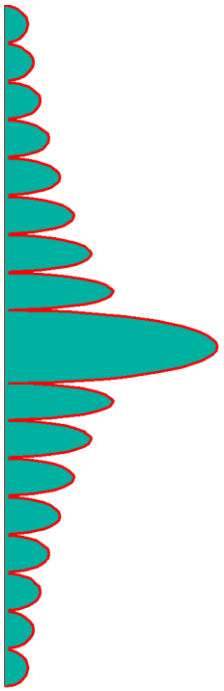
Loughborough University

THE SPHERICAL SPIRAL SCAN: EXPERIMENTAL VALIDATION



SPHERICAL NF-FF TRANSFORMATION

AUT FAR-FIELD PATTERN

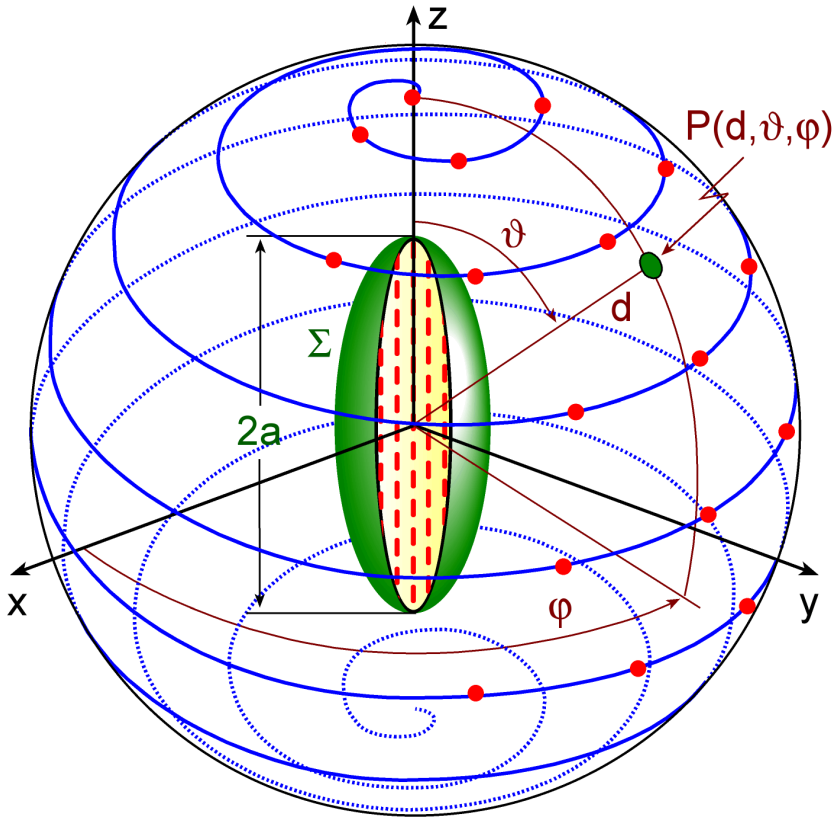


SPIRAL SCANS are obtained by means of continuous movements of the positioning systems of the probe and of the antenna under test (AUT)

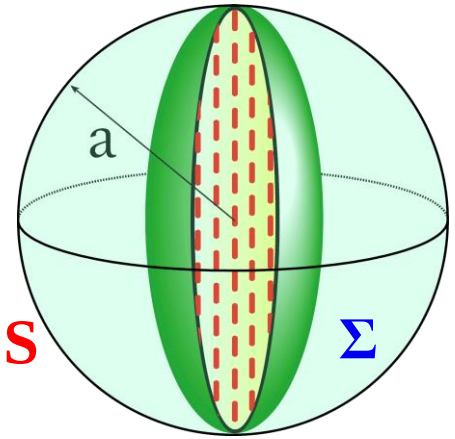
The reduction of the time needed for data acquisition

Loughborough Antenna & Propagation Conference

NONREDUNDANT SAMPLING REPRESENTATION: OPTIMAL SOURCE MODELLING



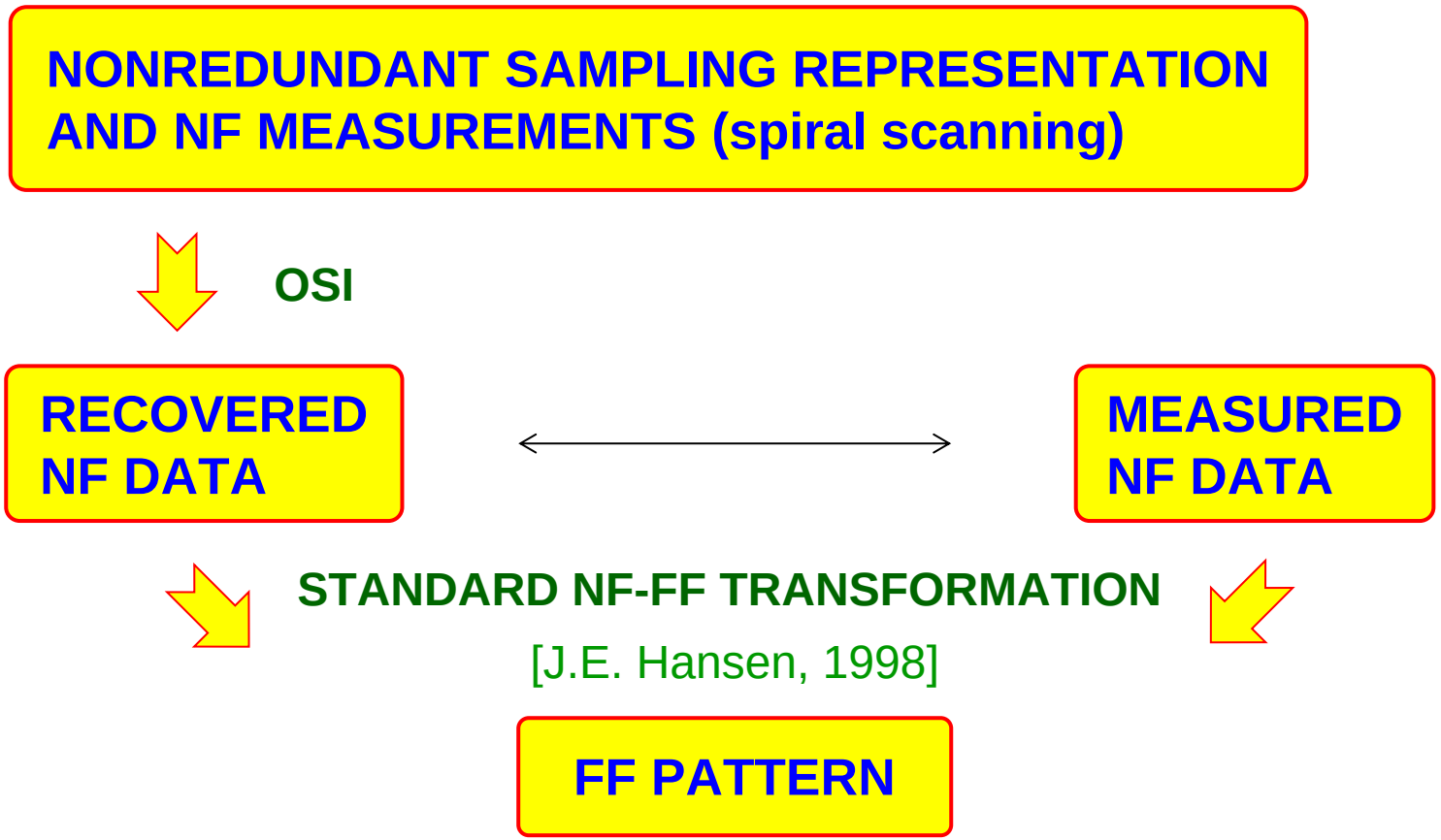
$$N_{\Sigma} = \frac{\text{area of } \Sigma}{(\lambda/2)^2}$$



area of Σ < area of S

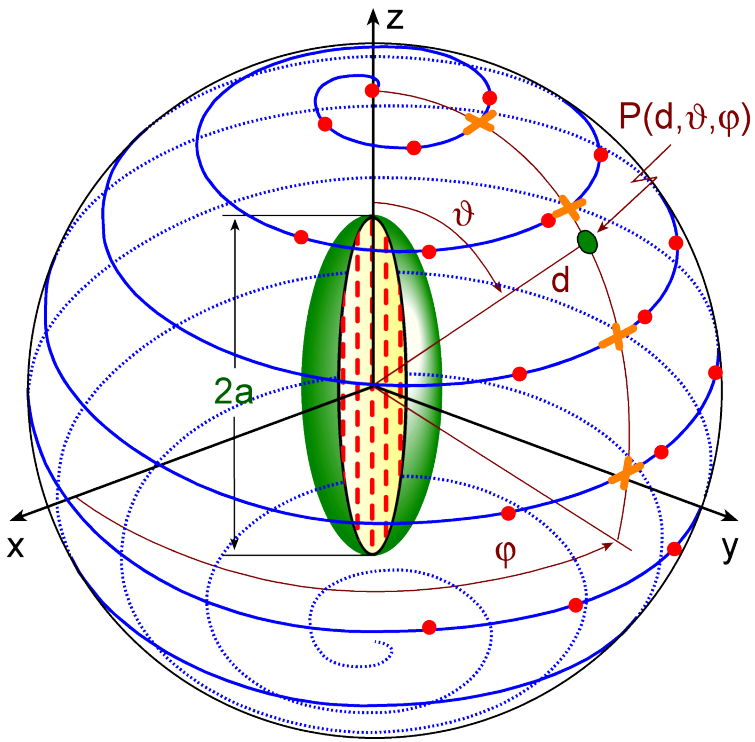
When considering elongated antennas, the spherical AUT modelling induces a volumetrical redundancy which implies an unnecessary increase in the number of required data.

EXPERIMENTAL VALIDATION: THE STRATEGY



THE INTERPOLATION SCHEME

$$\tilde{V}[\eta(\vartheta),\varphi] = \sum_{n=n_0-q+1}^{n_0+q} \Omega_N(\eta-\eta_n)\, D_{N''}(\eta-\eta_n) \sum_{m=m_0-p+1}^{m_0+p} \tilde{V}(\xi_m)\, \Omega_M(\xi-\xi_m)\, D_{M''}(\xi-\xi_m)$$



$$n_0 = \mathrm{Int}\left[\frac{\eta-\eta_0}{\Delta\eta}\right] \qquad m_0 = \mathrm{Int}\left[\frac{\xi}{\Delta\xi}\right]$$

$$\eta_n = \eta_n(\varphi) = k\varphi + n\Delta\eta = \eta_0 + n\Delta\eta$$

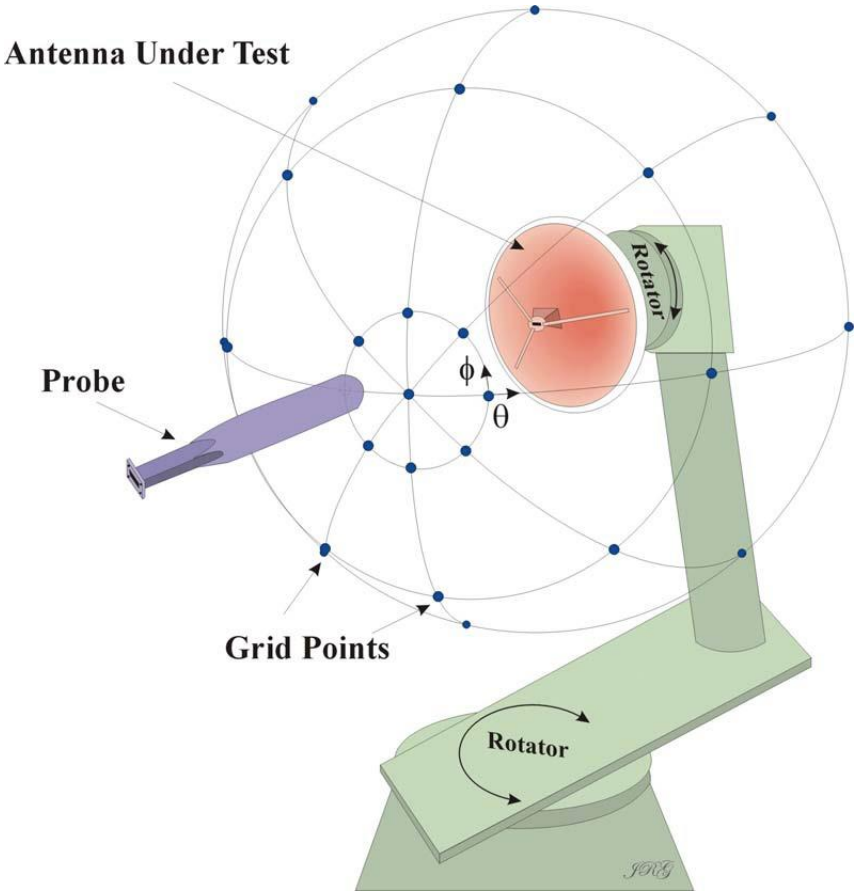
$$\xi_m = m\Delta\xi = \frac{2\pi m}{2M''+1} \qquad \Delta\eta = 2\pi/(2N''+1)$$

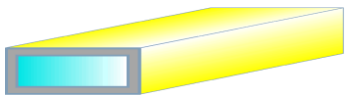
$$\begin{cases} M'' = \mathrm{Int}(\chi M') + 1 \\ M' = \mathrm{Int}(\chi' W_\xi) + 1 \end{cases} \qquad \begin{cases} N'' = \mathrm{Int}(\chi N') + 1 \\ N' = \mathrm{Int}(\chi' W_\eta) + 1 \end{cases}$$

$$M = M'' - M' \qquad N = N'' - N'$$

MEASUREMENT SETUP

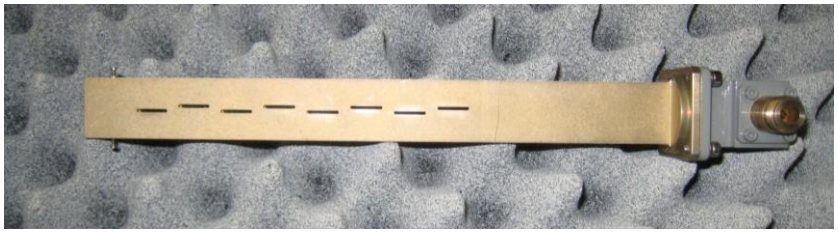
Test System

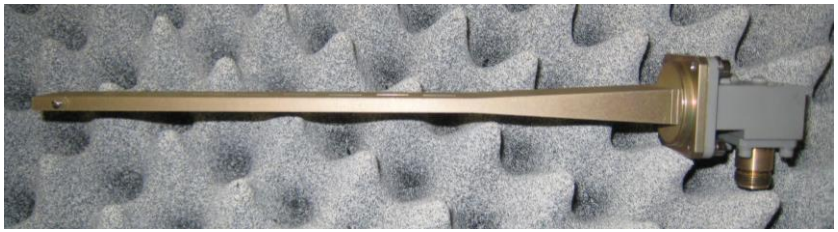




Probe: WR-90

Antenna Under Test





AUT: X-band slot array

AUT modelling: a = 6 λ

b = 1 λ

Scanning sphere: d = 15.07 λ

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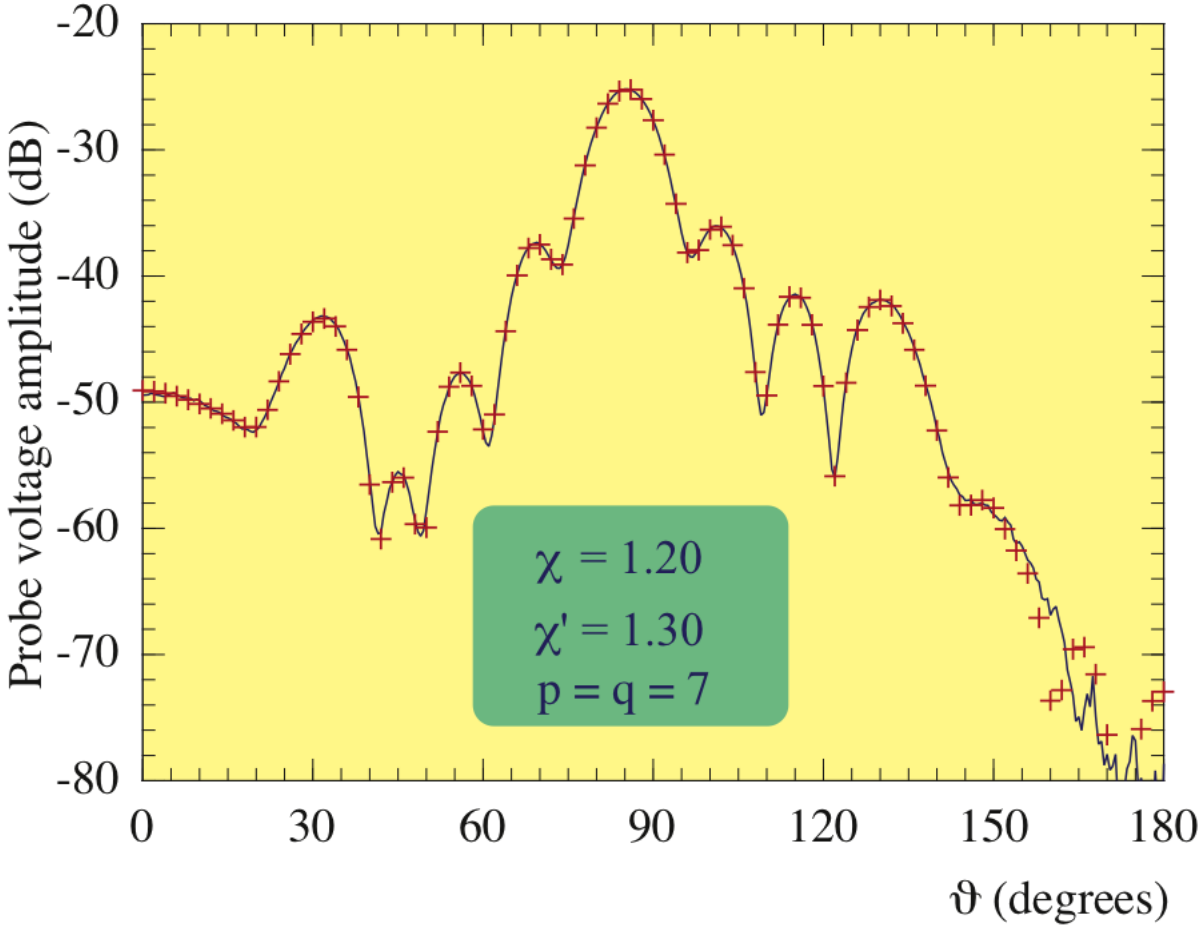
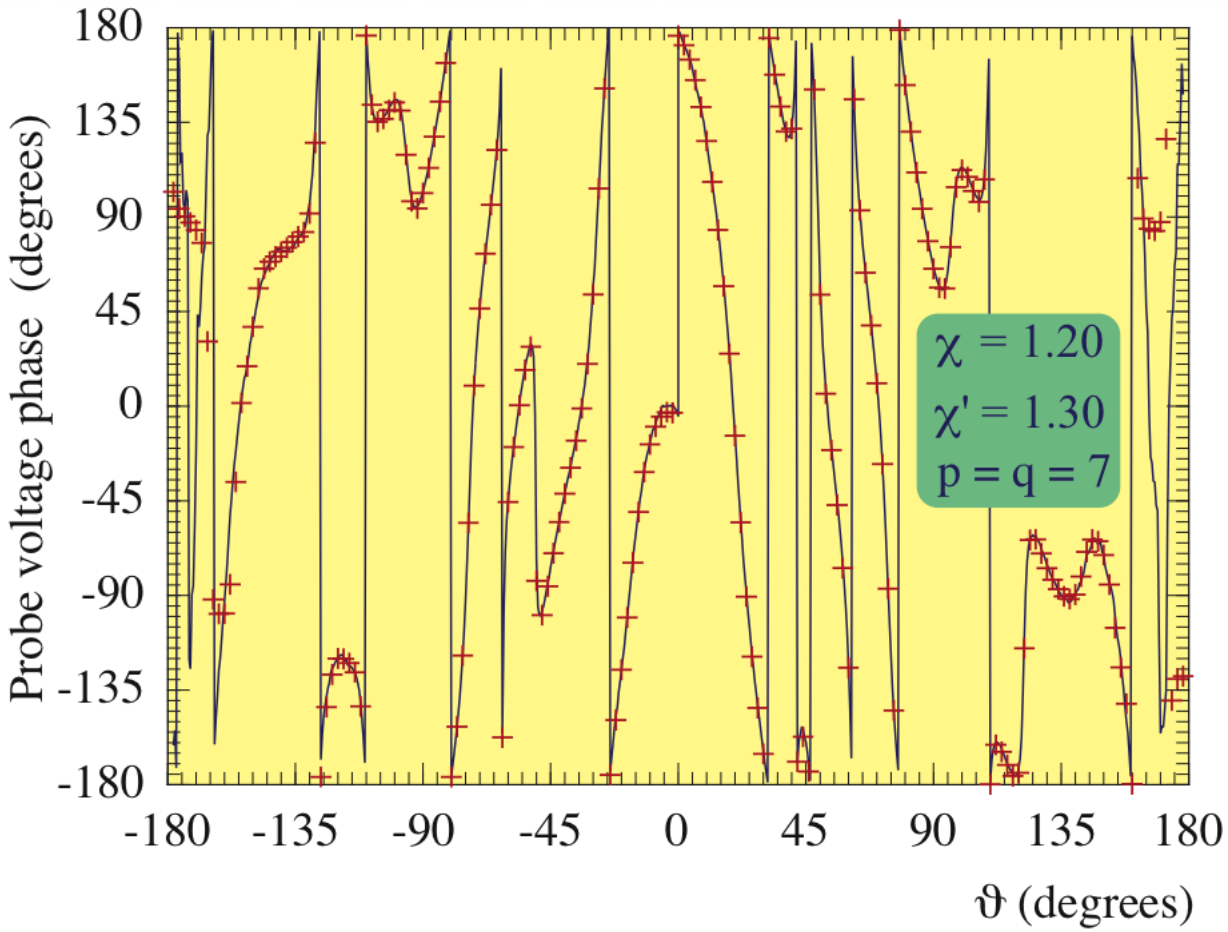
NF DATA



Amplitude of V_1 on the meridian at $\varphi = 0°$

Solid line: measured NF data.
Crosses: recovered from nonredundant NF data.

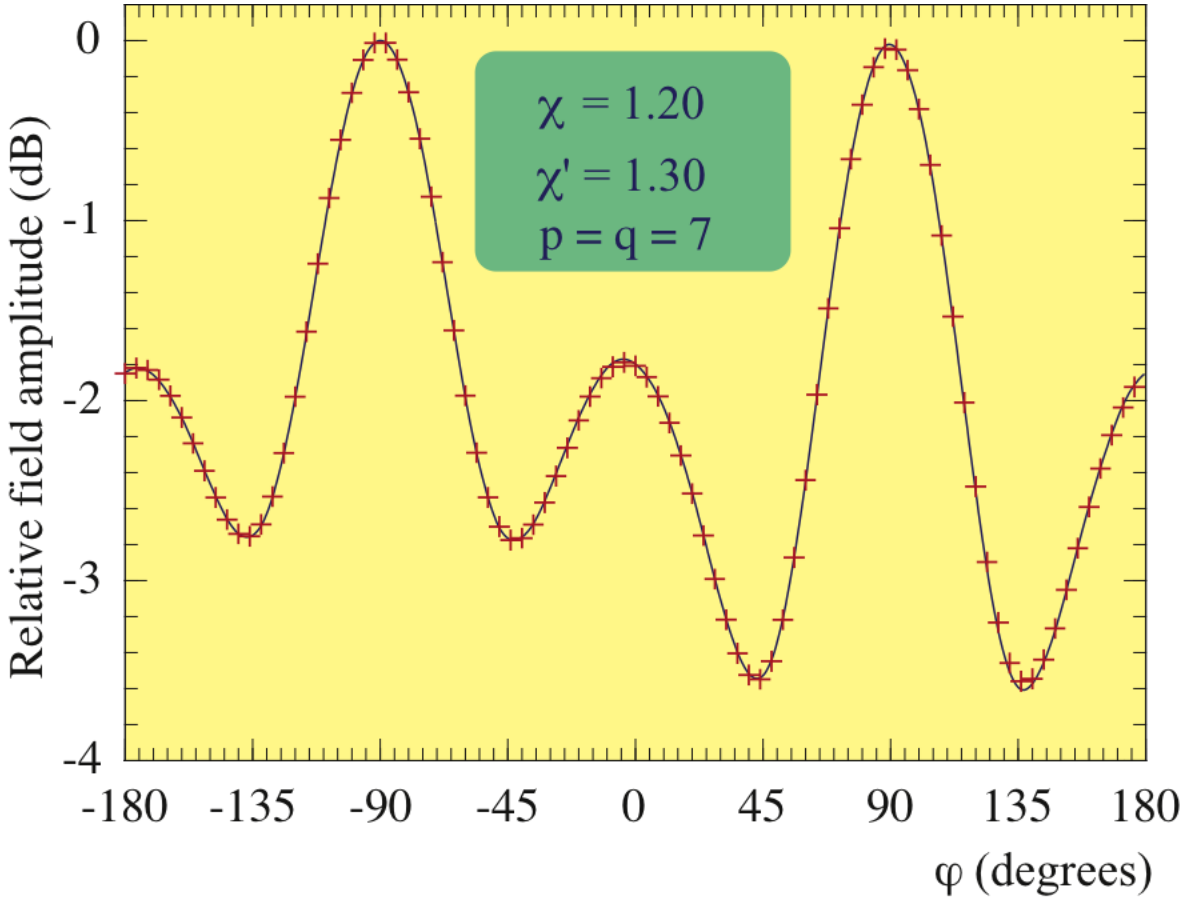
NF DATA



Phase of V_1 on the meridian at $\varphi = 0°$

Solid line: measured NF data.
Crosses: recovered from nonredundant NF data.

FF PATTERN

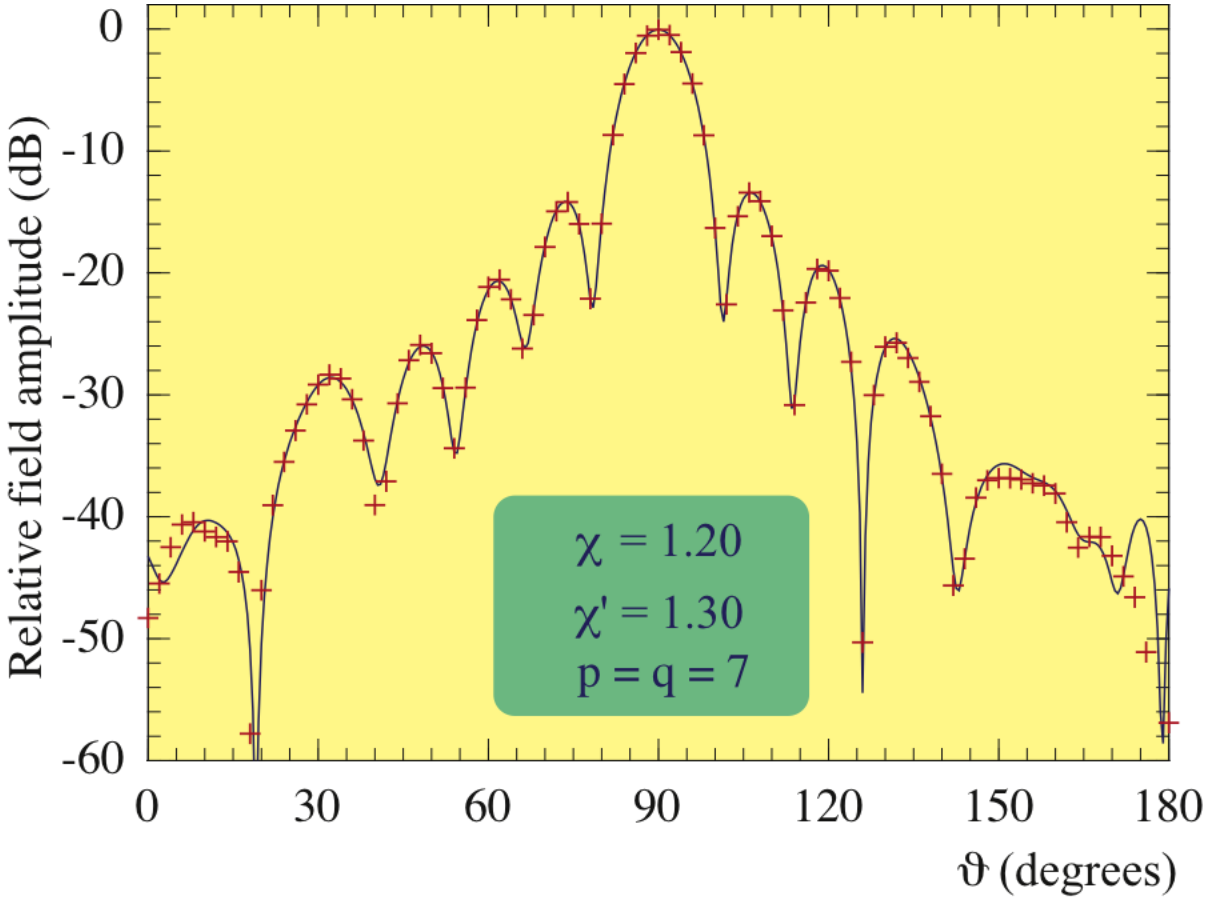


FF pattern in the E-plane

Solid line: from “classical” NF (measured) data.

Crosses: from nonredundant NF (measured) data.

FF PATTERN



FF pattern in the H-plane

Solid line: from “classical” NF (measured) data.

Crosses: from nonredundant NF (measured) data.

DATA NEEDED

Technique	NF data for the considered AUT
Classical approach [J.E. Hansen, 1998]	5100
Nonredundant approach	918

Experimental Proofs on an Effective Near-Field to Far-Field Transformation Technique with Spherical Spiral Scan Suitable for Long Antennas

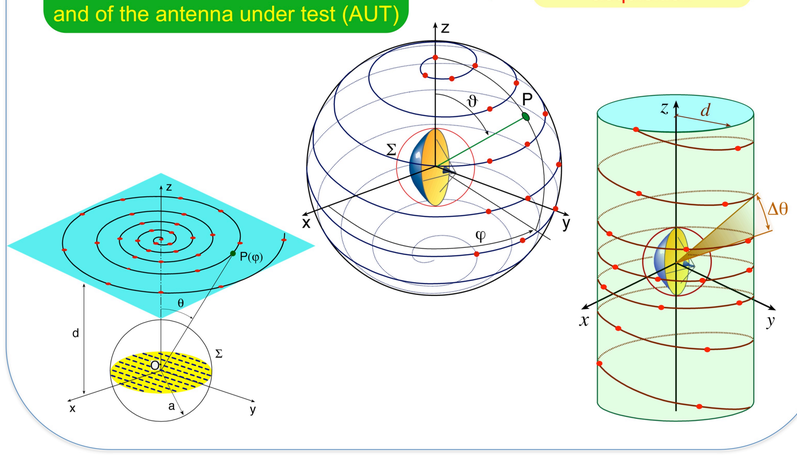
Francesco D'Agostino, Flaminio Ferrara, Claudio Gennarelli, Rocco Guerriero, Massimo Migliozzi
D.I.In. – University of Salerno, Fisciano (Italy)

This communication provides the experimental assessment of an efficient near-field – far-field (NF–FF) transformation with spherical spiral scanning for elongated antennas, which allows a remarkable measurement time saving with respect to the classical spherical NF–FF transformation. Such a saving is due both to the use of continuous and synchronized movements of the positioning systems and to the reduced number of NF data to be acquired. This technique relies on a nonredundant sampling representation of the probe output voltage, obtained by using the unified theory of spiral scans for nonspherical antennas and adopting a prolate ellipsoidal modelling of the radiating source. An optimal sampling interpolation scheme is then used to efficiently recover the NF data needed by a probe compensated NF–FF transformation with spherical scanning. The experimental tests have been carried out at the UNISA Antenna Characterization Lab and both the reported NF and FF reconstructions assess the effectiveness and reliability of the technique.

1 INTEREST AND MOTIVATIONS

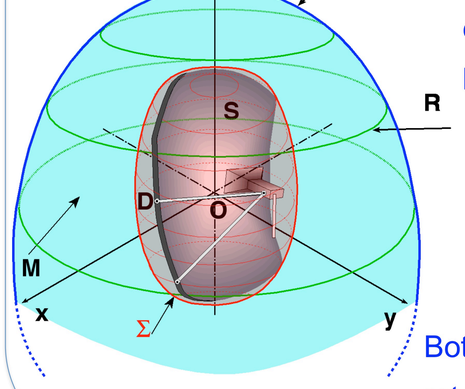
SPIRAL SCANS are obtained by means of continuous movements of the positioning systems of the probe and of the antenna under test (AUT)

→ The reduction of the time needed for data acquisition



2 THEORETICAL BACKGROUND

[O.M.BUCCI, C.GENNARELLI, C.SAVARESE, 1998]



S = source enclosed in a convex domain D bounded by a surface Σ

M = observation surface

Both Σ and M have the same rotational simmetry

3 THE REDUCED VOLTAGE

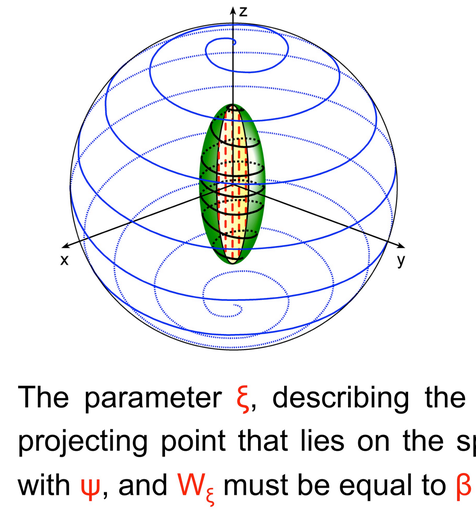
If the AUT is enclosed in a proper rotational surface Σ, and an observation curve is described by an analytical parameterization $r = r(\eta)$

"REDUCED PROBE VOLTAGE" → $\tilde{V}(\eta) = V(\eta)e^{j\psi(\eta)}$

$\psi(\eta)$ optimal phase function to be determined
$\underline{r} = \underline{r}(\eta)$ parameterization to be determined

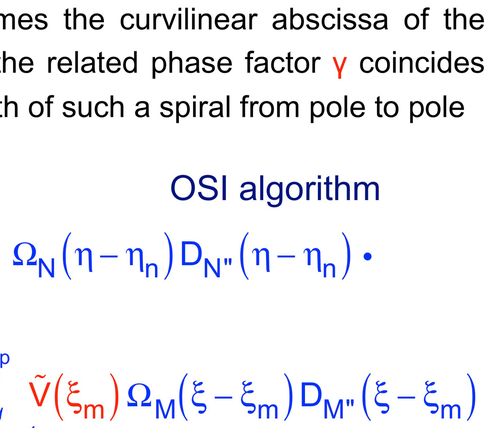
$\tilde{V}(\eta)$ can be approximated by a spatially bandlimited function, *[Bucci, Franceschetti, 1987]*

4 SPHERICAL SPIRAL SCAN FOR NONSPHERICAL ANTENNAS



When considering an elongated AUT, Σ can be conveniently chosen coincident with a prolate ellipsoid.

By adopting $W_\eta = \beta\ell'/2\pi$ (ℓ' being the length of the intersection curve C' between the meridian plane through P and Σ), the optimal expressions for the phase function ψ and the parameterization η to be used for describing a meridian become:



$$\psi = \beta a\left[v\sqrt{\frac{v^2-1}{v^2-\varepsilon^2}} - E\left(\cos^{-1}\sqrt{\frac{1-\varepsilon^2}{v^2-\varepsilon^2}}\,\middle|\,\varepsilon^2\right)\right]$$

$$\eta = (\pi/2)\left[1+E(\sin^{-1}u|\varepsilon^2)/E(\pi/2|\varepsilon^2)\right]$$

$$u = \frac{r_1-r_2}{2f} \qquad v = \frac{r_1+r_2}{2a}$$

$\varepsilon = f/a$ = the eccentricity of C' $\quad$ $E(\cdot|\cdot)$ = the elliptic integral of second kind

The scanning spiral is obtained as projection via the curve at η = const of that wrapping Σ

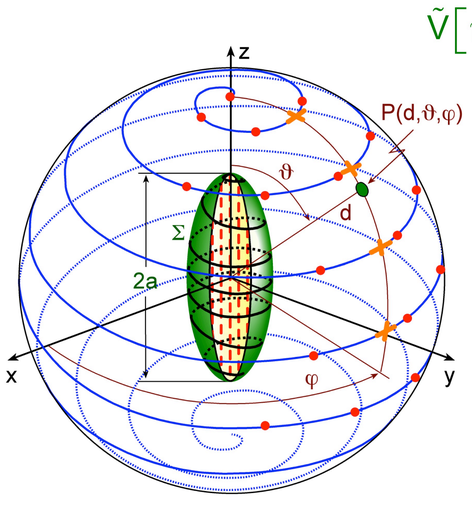
$$\begin{cases} x = d\sin\theta(\eta)\cos\phi \\ y = d\sin\theta(\eta)\sin\phi \\ z = d\cos\theta(\eta) \end{cases}$$

$$\eta = k\phi = \frac{\phi}{2N''+1}$$

$$N'' = \mathrm{Int}(\chi N')+1 \qquad N' = \mathrm{Int}(\chi' W_\eta)+1$$

The parameter ξ, describing the spiral, is β/W_ξ times the curvilinear abscissa of the projecting point that lies on the spiral wrapping Σ, the related phase factor γ coincides with ψ, and W_ξ must be equal to β / π times the length of such a spiral from pole to pole

OSI algorithm



$$\tilde{V}[\eta(\vartheta),\varphi] = \sum_{n=n_0-q+1}^{n_0+q} \Omega_N(\eta-\eta_n)\,D_{N''}(\eta-\eta_n)\cdot$$

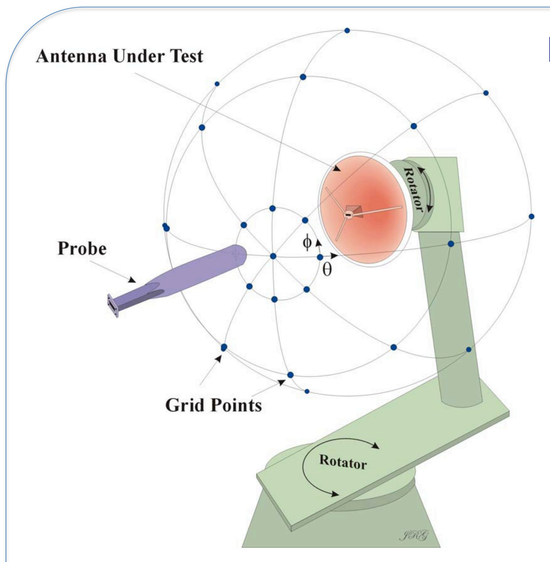
$$\cdot \sum_{m=m_0-p+1}^{m_0+p} \tilde{V}(\xi_m)\,\Omega_M(\xi-\xi_m)\,D_{M''}(\xi-\xi_m)$$

$$n_0 = \mathrm{Int}\left[\frac{\eta-\eta_0}{\Delta\eta}\right] \qquad m_0 = \mathrm{Int}\left[\frac{\xi}{\Delta\xi}\right]$$

$$\eta_n = \eta_n(\varphi) = k\varphi + n\Delta\eta = \eta_0 + n\Delta\eta \qquad \Delta\eta = 2\pi/(2N''+1)$$

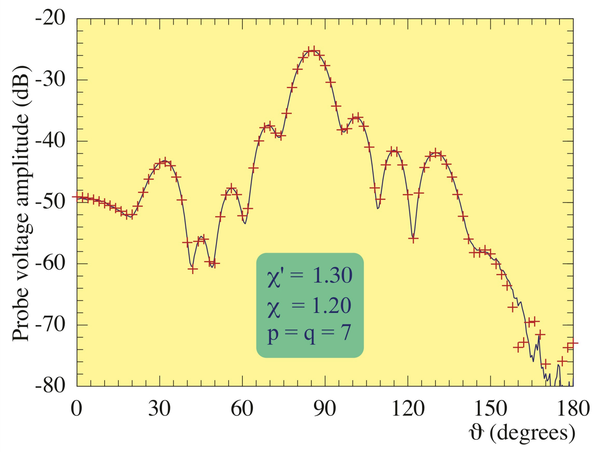
$$\xi_m = m\Delta\xi = \frac{2\pi m}{2M''+1} \qquad \begin{cases} M'' = \mathrm{Int}(\chi M')+1 \\ M' = \mathrm{Int}(\chi' W_\xi)+1 \end{cases} \qquad M = M''-M'$$

5 MEASUREMENT SETUP

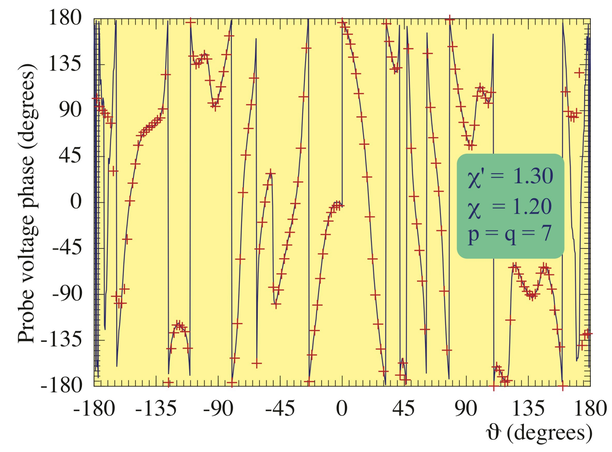


AUT: X-band slot array
AUT modelling: a = 6 λ, b = 1λ
Scanning sphere: d = 15.07 λ

# DATA	
Classical approach [J.E. Hansen, 1998]	5100
Nonredundant spherical spiral approach	918



Amplitude of the probe voltage on the meridian at φ = 0°.
Solid line: measured.
Crosses: recovered from spherical spiral data.



Phase of the probe voltage on the meridian at φ = 0°.
Solid line: measured.
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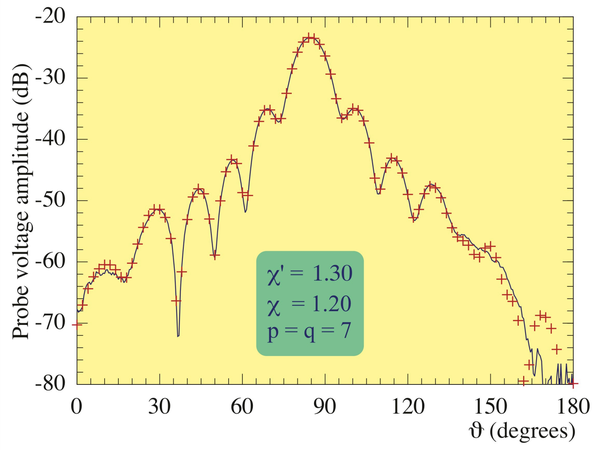
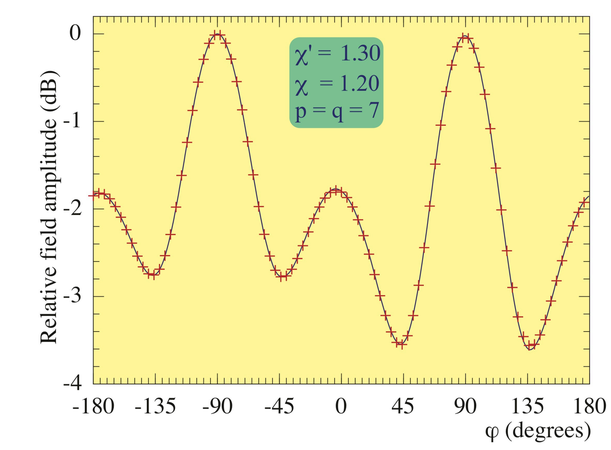
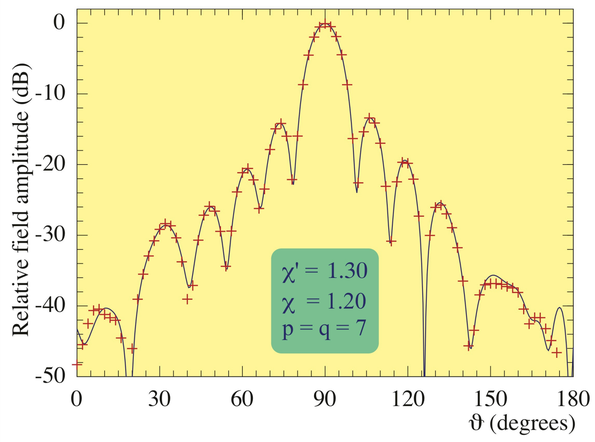


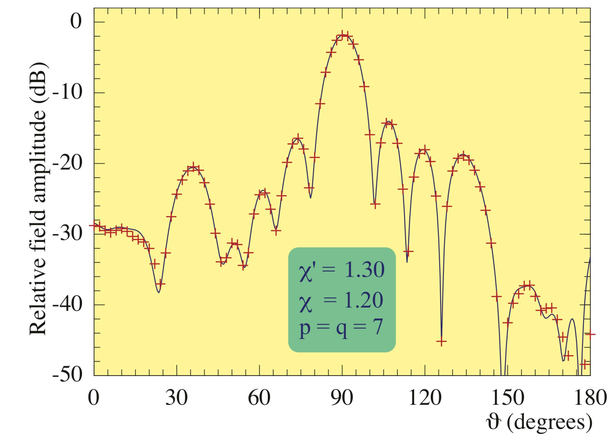
Amplitude of the probe voltage on the meridian at φ = 90°.
Solid line: measured.
Crosses: recovered from spherical spiral data.



E-plane pattern.
Solid line: classical approach.
Crosses: recovered from spherical spiral data.



H-plane pattern.
Solid line: classical approach.
Crosses: recovered from spherical spiral data.



FF pattern in the cut plane at φ = 0°.
Solid line: classical approach.
Crosses: recovered from spherical spiral data.